

Fig. 1

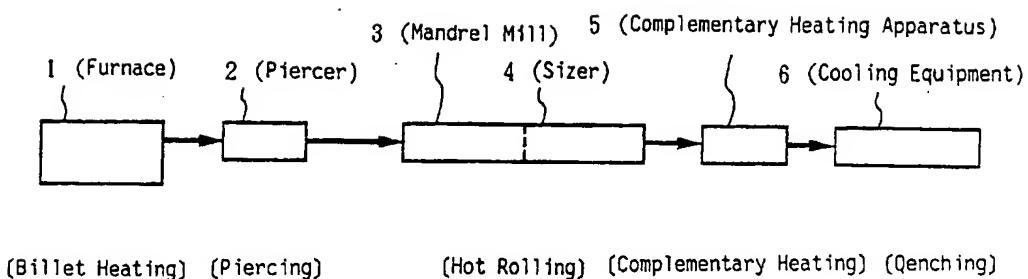


Fig. 2

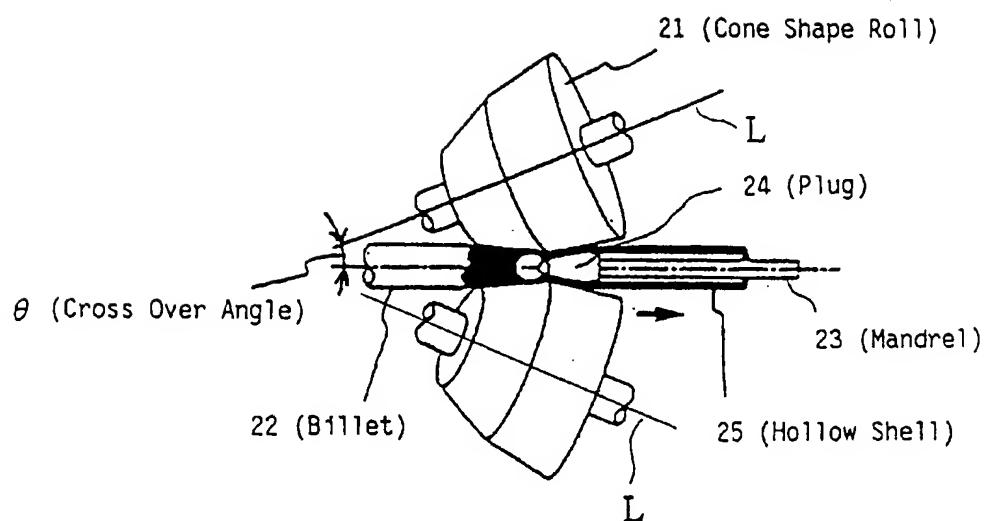


Fig. 3

Steel	Chemical Composition (weight %, Fe : bal.)								Others	f n 1					
	C	Si	Mn	P	S	Cr	Ni	Mo	sol.Al	Ti	Nb	B	N	O	
<i>Steels for the Process of This Invention</i>															
a	0.23	0.21	0.45	0.019	0.0011	0.54	0.01	0.69	0.013	0.025	0.032	0.0009	0.0025	0.0018	0.0161
b	0.25	0.28	0.39	0.014	0.0015	0.51	0.01	1.12	0.015	0.019	0.035	0.0008	0.0019	0.0022	0.0204
c	0.28	0.80	1.21	0.022	0.0042	1.05	0.02	0.43	0.018	0.008	0.103	—	0.0072	0.0022	Zr:0.015
d	0.45	0.25	0.53	0.031	0.0038	0.23	0.01	0.89	0.019	0.019	0.027	—	0.0053	0.0025	Ca:0.0018
e	0.22	0.34	0.48	0.013	0.0009	0.44	0.01	0.38	0.021	0.021	0.036	0.0007	0.0028	0.0015	W:0.82
f	0.23	0.42	0.49	0.017	0.0012	0.65	0.01	0.52	0.019	0.020	0.039	0.0011	0.0033	0.0018	V:0.18
g	0.24	0.04	0.16	0.015	0.0012	0.59	0.01	0.72	0.014	0.026	0.034	0.0009	0.0027	0.0015	0.0167
h	0.23	0.18	0.03	0.016	0.0013	0.53	0.01	0.69	0.011	0.021	0.035	0.0007	0.0023	0.0014	0.0131
i	0.24	0.03	0.04	0.016	0.0012	0.52	0.01	0.70	0.012	0.024	0.034	0.0008	0.0028	0.0021	0.0144
j	0.23	0.23	0.41	0.004	0.0010	0.54	0.01	0.71	0.017	0.022	0.037	0.0009	0.0018	0.0023	0.0158
k	0.22	0.22	0.42	0.012	0.0005	0.55	0.01	0.73	0.018	0.027	0.036	0.0008	0.0022	0.0019	0.0195
l	0.22	0.24	0.42	0.003	0.0004	0.55	0.01	0.71	0.019	0.022	0.035	0.0009	0.0023	0.0020	0.0141
m	0.23	0.05	0.06	0.001	0.0002	0.48	0.01	0.72	0.023	0.015	0.039	0.0008	0.0023	0.0014	0.0071
n	0.24	0.33	0.43	0.015	0.0010	0.54	0.01	0.15	0.020	0.022	0.037	0.0012	0.0032	0.0015	W:1.45
o	0.23	0.29	0.42	0.015	0.0011	0.45	0.01	0.31	0.018	0.012	0.038	0.0009	0.0023	0.0013	V:0.29
<i>Comparative Steels</i>															
p	0.25	0.36	0.55	0.023	0.0014	☆0.01	0.01	0.51	0.022	0.021	0.026	0.0008	0.0034	0.0015	0.0033
q	0.23	0.31	0.62	0.026	0.0019	0.72	0.01	☆0.01	0.025	0.022	0.021	0.0007	0.0029	0.0014	0.0121
r	0.23	0.28	0.52	0.026	0.0018	0.65	0.01	0.52	0.019	0.024	☆—	0.0008	0.0041	0.0020	0.0121
s	0.24	0.43	0.48	0.026	0.0020	0.68	0.01	0.43	0.024	☆—	☆—	0.0008	0.0035	0.0021	0.0120

Note: * f n 1 = Ti (%) - (48/14) × {N(%) - (14/9) × Zr(%) }
 ☆ Out of the scope of this invention

Fig. 4

	Test No.	Steel	Threshold Stress of SSC Resistance (kgf/mm ²)
Examples of This Invention	1	a	101.1
	2	b	102.0
	3	c	103.4
	4	d	103.2
	5	e	104.1
	6	f	106.5
	7	g	102.5
	8	h	102.3
	9	i	105.8
	10	j	107.5
	11	k	106.4
	12	l	108.0
	13	m	110.5
	14	n	105.6
	15	o	106.7
Comparative Examples	16	p	92.3
	17	q	87.9
	18	r	91.9
	19	s	89.1

Fig. 5

Test No.	Billet Heating Temp. (°C)	Reduction of Rough Rolling (%)	Total Reduction of Rolling (%)	Finish Rolling Temp. (°C)	Complementary Heating		In-line Quenching (°C)	Tempering Temp. (°C)	Quenching Temp. (°C)	Temper- ing Temp. (°C)
					Temp. (°C)	Time				
Examples of This Invention										
1	a	1150	50	80	900	870	30 min	23659	850	700
2	a	1250	50	50	850	950	1 min	23508	870	—
3	a	1200	50	60	900	950	5 min	24363	910	600
4	b	1250	30	50	1000	950	5 min	24363	870	710
5	b	1250	50	50	900	1050	2 min	25829	1020	—
6	b	1250	50	50	800	850	60 min	23583	830	600
7	e	1250	50	50	900	910	5 min	23566	870	680
8	e	1250	30	50	950	1000	1 min	24469	970	—
9	e	1150	30	40	850	910	5 min	23566	880	600
10	n	1200	50	50	900	900	30 min	24280	870	690
11	n	1250	50	70	900	950	5 min	24363	910	—
12	n	1250	30	40	850	910	5 min	23566	870	920
13	f	1150	30	70	950	950	5 min	24363	930	930
14	f	1200	30	50	850	960	1 min	23701	890	—
15	f	1250	40	50	1050	1100	30 sec	25978	1060	890
16	o	1150	40	70	900	900	30 min	24280	870	600
17	o	1250	50	50	1000	1050	2 min	25829	1020	—
18	o	1250	50	40	850	950	1 min	23508	930	600
19	—	1250	50	50	1000	950	5 min	24363	930	670
20	—	1220	45	45	1050	1100	20 sec	25737	1060	920
21	—	1250	40	70	800	910	5 min	23566	840	600
22	m	1200	50	70	1000	980	1 min	24085	970	670
23	m	1230	60	50	1000	1050	2 min	25829	1000	—
24	m	1250	50	60	1000	1000	5 min	25359	970	600

Note ** : fn 2 = $(T + 273) \times (21 + \log t)$. where T : Temperature (°C). t : Time (hr)

Fig. 6

Steel No.	Billet Heating Temp. (°C)	Reduction of Rough Rolling (%)	Total Reduction of Rolling (%)	Finish Rolling Temp. (°C)	Complementary Heating		In-line Quench- ing (°C)	Temper- ing Temp. (°C)	Quench- ing Temp. (°C)	Temper- ing Temp. (°C)
					Temp. (°C)	Time				
Comparative Examples										
25	a	1250	50	5	900	1100	20 sec	25737	1050	—
26	a	1250	50	50	*1110	950	5 min	24363	920	920
27	a	1250	30	70	950	1150	5 min	*28347	1100	690
28	a	1200	50	50	1000	* None	—	980	980	—
29	a	1250	50	60	900	* 700	30 min	*20140	680	680
30	m	1250	50	55	940	1100	20 sec	25737	1050	600
31	m	1250	50	50	*1120	950	5 min	24363	920	660
32	m	1250	30	70	950	1150	5 min	*28347	1100	670
33	m	1200	50	50	1000	* None	—	980	680	—
34	m	1250	50	50	*1120	*690	30 min	*19933	920	650
Conventional Examples										
35	a	1200	30	50	850	—	—	—	—	920
36	b	1200	50	50	1000	—	—	—	—	920
37	e	1250	50	70	900	—	—	—	—	920
38	n	1250	50	50	900	—	—	—	—	920
39	f	1250	50	60	950	—	—	—	—	920
40	o	1200	50	50	1000	—	—	—	—	920
41	l	1250	50	70	900	—	—	—	—	920
42	m	1200	40	40	950	—	—	—	—	920

注. * : Out of the scope of this invention
 ** : $f_n 2 = (T + 273) \times (21 + \log t)$, where T: Temperature (°C), t: Time (hr)

* as rolled

Examples of This Invention	Test No.	Steel	Yield Strength (kgf/mm ²)	Tensile Strength (kgf/mm ²)	Constant Load Test (Method-A)	S c Value	Toughness vTrs (°C)	Abnormal Grain Growth
	1	a	91.8	98.2	No fracture	10.5	-52	None
	2	a	91.2	97.1	No fracture	12.0	-66	None
	3	a	91.9	98.1	No fracture	12.0	-74	None
	4	b	90.3	98.1	No fracture	12.5	-69	None
	5	b	91.3	97.0	No fracture	13.0	-83	None
	6	b	91.0	97.7	No fracture	13.5	-83	None
	7	e	102.3	105.5	No fracture	11.0	-48	None
	8	e	100.3	106.7	No fracture	12.5	-65	None
	9	e	100.0	104.9	No fracture	12.0	-70	None
	10	n	102.0	107.1	No fracture	13.0	-71	None
	11	n	100.2	105.6	No fracture	13.5	-73	None
	12	n	100.4	106.4	No fracture	13.5	-74	None
	13	f	99.4	106.6	No fracture	11.0	-51	None
	14	f	100.4	106.7	No fracture	12.0	-80	None
	15	f	100.6	107.5	No fracture	12.0	-81	None
	16	o	100.7	105.7	No fracture	13.0	-73	None
	17	o	100.8	106.5	No fracture	13.0	-71	None
	18	o	100.3	104.7	No fracture	13.5	-70	None
	19	i	102.0	105.1	No fracture	11.5	-55	None
	20	i	101.4	104.9	No fracture	12.5	-78	None
	21	i	99.4	107.2	No fracture	13.0	-79	None
	22	m	100.8	105.1	No fracture	12.5	-63	None
	23	m	99.6	106.3	No fracture	13.0	-74	None
	24	m	101.0	106.2	No fracture	14.0	-84	None

Fig. 7

	Test No.	Steel	Yield Strength (kgf/mm ²)	Tensile Strength (kgf/mm ²)	Constant Load Test (Method-A)	S c Value	Toughness vTrs (°C)	Abnormal Grain Growth
Comparative Examples	25	a	90.9	98.0	Fracture	9.0	-29	Present
	26	a	91.9	98.3	Fracture	9.5	-15	Present
	27	a	90.8	98.2	Fracture	11.5	-38	None
	28	a	91.4	98.1	Fracture	9.5	-44	Present
	29	a	49.9	75.0	Fracture	9.0	28	None
	30	m	100.2	105.9	Fracture	8.5	-24	Present
	31	m	102.1	107.0	Fracture	9.0	-19	Present
	32	m	102.0	106.9	Fracture	11.0	-41	None
	33	m	100.6	106.6	Fracture	10.5	-48	Present
	34	m	53.1	77.0	Fracture	9.0	21	None
Conventional Examples	35	a	90.9	96.7	Fracture	11.5	-68	None
	36	b	90.6	106.6	Fracture	12.0	-48	None
	37	e	99.8	105.1	Fracture	11.5	-42	None
	38	n	100.8	106.1	Fracture	12.5	-52	None
	39	f	99.6	107.5	Fracture	12.0	-55	None
	40	o	100.6	107.3	Fracture	12.0	-46	None
	41	i	100.6	106.6	Fracture	10.5	-48	None
	42	m	101.7	105.1	Fracture	12.5	-49	None

Fig. 8